COGSWELL & COGSWELL

Monolithic Concrete Construction

Architectural Engineering

B. S.

1911

MONOLITHIC CONCRETE CONSTRUCTION

BY

ROBERT COMAN COGSWELL
GEORGE OWEN COGSWELL

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

ARCHITECTURAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1911

UNIVERSITY OF ILLINOIS

June 1, 1911 ~~190~~

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Robert Coman Cogswell and George Owen Cogswell

ENTITLED Monolithic Concrete Construction

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in

Architectural Engineering

James M. White
Instructor in Charge

APPROVED: Frederick M. Mann

HEAD OF DEPARTMENT OF Architecture

Table of Contents.

MONOLITHIC CONCRETE CONSTRUCTION.

Art.1. Historical- general.

Concrete is by no means a new building material, for concrete construction dates back to the time of the Romans, who were the most notable users of this material, though entirely as a useful substitute for a more costly masonry, or as a material for rough walls which could be faced with brick or stone. These pioneers of concrete construction used a mixture of slacked lime, volcanic dust, sand, and broken stone, and secured good results with this combination crude in comparison with the Portland Cement concrete of our present day, and produced an artificial stone which has stood the test of nearly two thousand years. This is evidenced by the many works in Rome, which are today in a perfect state of preservation.

Art.11. Growth of Portland Cement.

Portland Cement, which is an essential of concrete, is an invention of modern times, and its universal use a matter of a quarter of a century. The honor of its discovery belongs to Joseph Aspdin, of Leeds, England, who took out a patent in 1824 for the manufacture of Portland Cement, so called because of its resemblance in color to the popular limestone quarried on the island of Portland. Manufacture was begun in 1825, but progress was slow until about 1850, when through improved methods and general recognition of its merits as a building material, commercial success was assured. About this time, the manufacture of Portland Cement was taken up in earnest by the French and Germans, and by reason of their more scientific efforts, both the method of manufacture and the quality of the finished product was greatly improved. The wonderful success and development of Portland Cement in all forms

of construction has come to be the subject of general knowledge, and consequently, the public mind is inclined to accept this new idea of monolithic construction not only for its monumental buildings, but also for house construction with confidence in its possibilities. Portland Cement was first brought to the United States in 1865, and its initial manufacture in this country was in 1872. In 1891 the annual output was about 500 000 bbls, five years later it reached the 1 000 000 bbl. mark, and it is estimated that the output today is nearly 75 000 000 bbls. Reinforced concrete dates from 1855, when one M Lambert, of Paris, constructed a small row-boat of cement mortar and wire netting. From then on, the practical application and use of reinforced concrete has been very broad, very popular, and productive of very surprising and pleasing results.

Art. III. Concrete as a building material.

Many things have contributed to make concrete one of, if not the most important of building materials of the day. This is shown in its worth as a substitute for wood, its moderate cost, its durability, the ease and speed with which it can be handled, its stability and strength, the wide distribution of sand, gravel, and stone which enter into its composition, and the tremendous growth of the cement industry. It has been thoroughly tried and tested not only in the laboratories, but also by years of actual use by the United States government, by agricultural and engineering colleges, by railroads, most of which have adopted it universally as a building material, stock-yards, and by hundreds of farmers, property owners and architects. That it will eventually become the best building material known, is already beyond the question of a doubt, for it not only possesses the properties of every other

building material known, but while all other materials deteriorate with age, this substance grows better. The increasing cost of other materials is but another point in its favor.

Art. IV. Result of growth of Portland Cement.

Monolithic concrete construction will obviously be the outcome. Many things point to this which will be considered later. Many changes will be made in the design of such buildings, methods of conducting the work, and proportioning the concrete used, but there is no doubt that safe, sanitary, fireproof, durable, attractive, and economical buildings, either for factory or residence purposes, can be made of concrete. Those who have studied the matter from different view-points say with good reason, the not only are these destined to be considered cheap, though none the less well built structures, but can also be treated to suit those for whom attractive design, and not economy, is the chief item of interest. In supporting this latter statement, we find that the idea of a monolithic structure appeals more and more to the architects and owners of costly houses. The absence of joints, which are necessary to all unit construction, the impervious character of walls and floors, which may be decorated so as to make ornamental features an integral part of the structure instead of a superficial interior coating that may harbor disease, dust and vermin, to say nothing of the possibility of destruction by fire, appeals strongly to the architect and individual and family who will occupy the house. If there is any reason in the world why concrete should be adopted for cheap houses, it becomes imperative in the case of costly houses containing furniture, fittings, and treasures of great value. The time is coming when people will object to a wall that can easily be crushed

with a hammer, disclosing combustible studding and hidden recesses through which fire may travel until it comes in contact with floors and roofs of the same combustible material.

Art. V. Object of Thesis.

In considering monolithic concrete construction as a subject for a Thesis, the main idea was to learn what is being done along these lines, and it will be impossible to treat all the phases which the subject suggests. We shall, therefore, consider a few of the most important questions which arise. Of these, the two which require the greatest thought and care in solving, are the adaptability and possibilities of design, and the question of forms. These are the most important to be considered in monolithic concrete construction. We are not treating the subject in its purely technical sense, nor are we considering the problems of reinforced concrete as a material to resist tension and compression and other stresses. In seeking material for the subject, we searched those magazines and publications which are considered as authoritative in information, experienced in their various lines of work, and honest in their opinions. We have reviewed the files for a number of years standing, and have written letters to many firms interested in concrete directly or indirectly, and have also written to those who have given the subject of forms for monolithic concrete construction the most careful consideration. We have read articles in the leading publications of men whose reputation for truth and skill along their respective lines insures the worth of their opinion. We have reached some definite conclusions as the result of our reading; we have obtained a better idea and clearer understanding of the possibilities and advantages of monolithic concrete construction, than was had here-

to-fore. And so, though we may neglect what might seem to some all-important, and may have emphasized apparently unimportant points in this subject, we hope that we have proved that in the near future the development of monolithic concrete construction will reach a point far in advance of what has been done in any other line of building methods. Reinforced concrete, unlike wood, steel, brick, and other building materials, improves with age, does not require painting, and has great fire resisting qualities. It might be well to state in brief the points that are to be discused in this Thesis in favor of monolithic concrete construction. It is not our purpose to investigate the problems that the subject of reinforced concrete as reinforced concrete suggests. That, in itself, has formed the basis of many books and papers far more comprehensive, more thorough, and more technical, than the limits of this Thesis will permit. The main points to be brought out are the possibility and adaptability of monolithic construction to architectural design; the speed with which a building of this type may be erected; the cheapness; the durability, which includes proof against fire, storm, and age; sanitation; and stability. These points include many others which will be taken in as reached.

Art.VI. Possibilities of the material for building.

If some inventive investigator were to evolve at a moderate cost, a construction material, possessing the lightness of wood, the strength and rigidity of steel, the color variety of brick, and the weathering properties of bronze, radical changes in constructive design would sooner or later follow. Such a substance would possess qualities so different from those of a single material at present known to constructive art, that the application and method of architectural treatment

would be radical departures from technical paths. It would find uses never dreamed of by its predecessors, and the elements made of it would be dimensioned according to entirely new rules, and the canons of decorations and embellishments completely revised. It's would at first, be put to uses by enthusiasts for which it would not be adapted. It's method of architectural treatment would probably at first follow that of the old materialswhich it was designed to replace, and illogical designs and offensive imitations would result. Time and experience would eliminate defects and a logical style would ensue. However, such changes must be gradual because, for centuries architects and craftsmen have built in traditional materials, and the systems of construction, architecturally and structurally, in keeping with these materials, have the sanction of age and the approval of custom. Concrete has within the present generation entered the field, and because of its many advantages, the increasing cost of materials which it is gradually replacing, is destined to grow in importance. The place, however, could not be quickly won. In some respects, it is analogous to our hypothetical material. Its manufacture and its properties, make it like our material just discussed, and in many ways an absolutely new material. There are two things which must guide us in the quality of material and architectural treatment. In the first place, it is a molded material; in the second place, its masonry is monolithic and continuous, that is to say, not jointed. Ornament, if in the mass, will be an integral part of the whole, and must grow out of it, and should not, as with brick or stone masonry, consist of added units. House moldings and cornices, not suggestive of masonry, are quite permissible, but brackets for the support of cantilever projections are inconsistent with its mechanical

properties.

Art.VII. Possibilities of design.

The possibilities of design are those of brick, stone, and terra cotta, and not as block construction, but as a plastic material. In block building, joints are essential, and as elements of the design should be accentuated. For instance, any of the classic orders, or their modifications in the Renaissance, and the frank sucession of blocks and columns set upon plinths, or directly upon the basement walls, cap, or abacus, frieze or cornice, are built up stone upon stone, with the major joint marked by moldings, bead, or ornament. This would be impracticable with a material of a plastic nature, for the design is a matter of extended form and not a true expression of the material used. Concrete is made with shovel and trowel, and its proper ornamentation should be either cast in the molds as built, or such as may be run or fastened upon the work, with the addition of such color ornament as may be obtained with terra cotta or other protecting material, such as wall copings, pier caps, and other flat color ornamentation, as is often expressed by the use of tile, marble, glass, or other material that may be applied to the surface. This means a vast departure from the classic forms and accepted styles of the past. It is, in fact, a new style of architecture. We shall want walls, windows and doors, in any case, and they must be built in the accepted form, but with such plastic material as concrete, the openings and moldings may be made to vary in form from those designed by the architects in the past, who depended upon arches and lintels. In Spanish, Californian, and Mexican Spanish styles, their plastered walls, tiled roofs, and wall copings, suggest concrete more than brick, and their domes and covered pediments

are suggestive of plastic rather than block construction.

Art. VIII. Architectural features of reinforced concrete.

The architectural features of reinforced concrete should be of the molded type, and for this purpose hollow forms are required. As elaborateness of design necessitates great labor and expense in the form making, such enrichment must be simple, and other methods must be sought. The monotony of blank wall must be relieved, and the use of brick and tile in conventional designs has been attended with much success. These can be used for decorative purposes in such a way that the building may keep all the characteristics of a monolithic structure. If stucco is applied to a monolithic structure, it is advisable that the wall be cast in the rough so that the stucco may adhere better. The form may also be faced in such a way as to make a good effective exterior. Tile or colored brick may be placed inside the forms, so that when the concrete is poured, a solid monolithic wall with tile or brick facing is produced. The use of the bush hammer is also effective. Texture of the solid wall may be improved in other ways. If the work is such that the forms may be removed in twenty four hours, that is, before the final hardening has progressed very far, a surface of uniform color and texture may be obtained by rubbing with a wooden float, and this may be done with unskilled labor. Another method is by scrubbing with a wire brush, and still another is by blasting with compressed air. Outer skin and adhering sand and cement are removed, and underlying aggregates exposed in a manner similar to that in which brushes or solid washes are employed. Mr. R.L.Humphrey, in an address before the Concrete Institute of London, stated that one discovery that he had made on his recent trip abroad, was that concrete could be polished as sucessfully as marble.

Art.IX. Construction and surface treatment.

In factories and mills, concrete is a good substitute for wood, steel, and brick, to a certain extent. Concrete, structurally, is much used, and with a very strong assurance of its success to withstand strains and to hold up loads. But the problem of producing a pleasing surface finish is one in which the architect is not yet ready to guarantee results. In the early days, when Europe's architectural monuments and structures were erected, without any thought as to the strength of materials or the stresses to which they were subjected, the architect and the engineer were one and the same, and no line or distinction of any kind was made. Later, two sets of builders grew up; one, the architect, who built entirely for beauty, and the other the engineer, who built solely for strength. Concrete is, primarily, the engineer's material, because of the manner in which it can take and resist stresses, and it has stood exclusively theirs with the lower grades of materials, as natural cements and hydraulic limes. But in the present day conception, with the strong competition, even with the increasing cost of all building materials, the best of concrete can be made, and still the cost of building with that material would be lower than the cost of building with any other material. In endeavoring to treat the surface smoothly, the mistake was made in attempting to imitate stone, even when cast as a monolithic, it has been put up to imitate separate blocks of masonry, elaborately carved cornices cast in concrete, copings and gargoyles, griffins, and pilasters. Everything that has been made in stone has been imitated in concrete with disappointing results. True architecture of concrete will come when the imitation is abandoned, and concrete is recognized as a material capable of its own especial treat-

ment for the production of architectural effects otherwise impossible. Such architecture has not, as yet, been developed. The architect, by virtue of his skill and training, is the only professional judge of the beautiful in construction, and beauty in concrete structures will only come when the architect will abandon his prejudice against it, and regard it impartially as a new material to be treated in a new way. A good architect is an artist, and to him, as to Keats, "Beauty is truth, and truth is beauty, and that is all we know and all we need to know". It is the architects idea to produce the beautiful in structures. When, therefore, concrete, which to the architect says, "Imitation", is used for truth, there is no truth, and hence no beauty, and when he realizes that it is a separate and distinct material, and that of it, structures can be built as strong as any of the engineers of the old school could wish, and nearly as cheap as some of its promoters claim, and, after its own individual style, as beautiful as any masonry structure, then, and only then, will be developed its true architectural beauty which will endure. Efforts of all engineers should be to this end, and designers of concrete structures should abandon all shams and deceptions, in the endeavor to make the material stand forth for what it really is. Surface treatment is one of the main points, and there are a great many methods of treating it.

Art. X. Conclusions as to design.

From the foregoing remarks, it seem to us very evident that a logical style is on the eve of development, and that the dominating principle of it will be the harmonization of treatment with the functional characteristics of the material employed. That is to say, monolithic concrete construction is adaptable to good architectural design, and

the material must be treated as an entirely new one; and in the design, new principles will be called forth. It is a plastic material, and must not be confused with wood, steel, or brick, which are materials of more or less rigidity. Along lines of simple and direct expressions of purpose and mode of construction of buildings, architecture grows when it is really expanding and developing, and concrete in the manifold possibilities spreads before us a new field of imaginative design.

Art. XI. Examples of design. Blenheim Hotel.

Among the many good examples of good design in concrete buildings, the Blenheim Hotel takes rank as one of the most complete examples of the subject in hand. There is no suggestion of the built structure in its wall openings; the moldings are few and simple, and the lack of an elaborate cornice is noticable. The solid walls with their simple openings reduce to a minimum the chopped up appearance common with buildings that have many windows and small unbroken surfaces. Where bay windows occur, the shadows from the balconies have been used to give the relief usually obtained by ornamental cornices, and with the addition of tile roofs, and colored tile, sufficient color and variety has been secured to make a building which is essentially plain in wall surface, yet giving a sense of richness not always obtained by the use of elaborate and expensive ornamental work in stone and terra cotta. The use of a moderate amount of terra cotta for sills, copings, and other wall projections, has been made unusually important by modeling in a light green by a glaze which has the additional advantage of destroying any semblence to stone, and giving the plastic character necessary for modeled ornament. By running the molds with concrete into which the color has been introduced, it would seem as though we could get the same effect

as by the use of the above mentioned tile.

Art.XII Example of design.

Another example of a problem of decorative design for monolithic concrete construction is given in a paper by M.Albert Mayer, of New York, read before the annual Convention of Cement Workers at Buffalo, New York. It is a detailed account of exposed selected aggregates in monolithic construction. As an example of what can be done a residence erected at South Orange, N.J., was described. The walls were built of concrete made of carefully selected aggregates of uniformly small size and of variegated and brilliant color. The forms were removed the next day after the laying of the concrete and the exterior surface scrubbed with brush and water until these stone particles stood out well from the mortar matrix, and the dirty face which usually flushes to the surface had been removed. The result, as can be imagined, was unusual as well as pleasing, and only served as another answer to the question of treatment of wall surface. In this connection, illustrations were shown of the interior of the new Racquet Club in Philadelphia, in which the interior is composed of rough concrete as it comes from the forms, with the addition of inlaid parti-colored tiles. This in no way changed the character of the monolithic structure, as the tile became an integral part of the concrete even as the surface concrete is.

There are many more examples of concrete construction as used in railroad bridges, viaducts, and etc., and in almost every line of work that requires any sort of building material, so that it is safe to assert that as regards versitality of design, concrete enjoys a wider range of possibilities than any known building material. This, taken with the conclusion reached as to the ultimate development of the in-

dividual design for concrete construction, argues exceedingly well for its adoption as the universal material for building.

Art. XIII. Durability of concrete.

For the construction of any building where the safety of the contents is the important consideration, a material must be chosen that will withstand fire, shocks, atmospheric deterioration, and the attritions of time. Concrete possesses possibilities that justly claim consideration along this line, and we shall for the present consider what it has done, and what it can do to be entitled to the claim of durability. Many well-intentioned persons, ignorant of building in its broader sense and apparently ignorant of the simple customs of concrete have brought about failures which have caused not only loss of time and material but loss of life also. These failures on the natural side have been attributed to all sorts of reasons, some possible and some impossible. We are told that concrete is liable to disintegration of various kinds, that water will dissolve its substance, that it may be asphyxiated by escaping gas, that it can be weakened by electricity, and can succumb to an attack of electrolysis, that its strength depends upon the proper and permanent setting of the cement, but that no one knows how long cement will stay set.

That the Romans were familiar with concrete and gave careful consideration to its use, examination of the concrete work of that country clearly shows. The analysis of this concrete reveals it as similar to our concrete, although the cement used was not as good as the Portland Cement in use today. The Romans mixed their cement exactly as we mix ours, in a general batch of stone cement and lime, which after being worked, was thrown into wooden forms. The marks of the wooden forms

are at all times discernible and especially is this so in the corridor of the house of Agustus in the Palatine where the grain of the wood can clearly be seen. Their walls rise above the ground and there is a splendid opportunity to see the concrete and leisurely inspect it from every point of vantage. Above these concrete foundations rises the palace of Agustus formed of stupenduous walls and vaults of brick. The structure of brick above these concrete walls has yielded to the ravages of time and succumbed to the hand of the destroyer, but the concrete remains without a crack or fracture. It adhesion is perfect and there has not been the slightest disintegration of even the outer surface as the grain of wood of the forms still shows after two thousand years. The Arch of Titus rested on a monolithic base of concrete which was poured into wooden forms and in part of the ruins of the Temple of Julius there is a large concrete base on which the marks of the wooden forms are still visable; the state of preservation is perfect, there is not a crack or a fracture in it and, though it is located in a nasty part of the Forum, it shows no effect from the moisture to which it has been subjected for so long a time. These facts give convincing testimony as to the efficiency and durability of concrete and impels us necessarily to the conclusion that we have no building construction which, viewed from any standpoint, measures up to the standard established by concrete.

Economy in railroad construction demands permanent structures. Materials must be used which are, so far as is possible, proof against deterioration and destructive influences of the elements and vibration. It must resist corrosion, decay, and fire and the gradual weakening due to continual, severe, and constantly growing service. At the same

time the materials must possess the requisite strength for present and future traffic combined with cheapness and facility of construction. While steel and wood structures grow weaker from rust and decay, a concrete structure grows stronger with time and its life is measured by ages rather than years. In addition to its natural permanence, such a structure is proof against tornados, high water, fire, and earth-quake. A number of buildings in San Fransico withstood the shock of the earthquake while those around them built of terra cotta, brick, and stone were destroyed.

Art.XIV.Proof of durability of concrete.

Much more could be said of the durability and lasting qualities of concrete construction over other types of buildings and a large number of examples could be given to substantiate such statements. Fireproof qualities of concrete are so unusual, so strong in their appeal to the builder, that a separate point is made in that consideration of monolithic concrete construction.

Numerous fire tests have been made to determine both the resistance of concrete to actual tests and also the depth to which the reinforcement must be embedded to prevent its being damaged. The maximum depth of pitting in actual fire tests where a temperature of 1700°F. or more had been maintained for a period of five hours, has been found in either walls or ceilings to be one to one and a half inches. Also by examination of actual conflagration as at Baltimore, San Fransico, and elsewhere, it has been apparent that the pre-arranged fire tests are more severe in the results shown by the structure than actual conflagrations. If we can protect the material against damage in a pre-arranged test, it will stand any actual service.

Art.XV. Fire test.

Another fire test which is very notable for its results was made in 1907 on a reinforced concrete floor, the span of which was fifteen feet. The slab was loaded with pig-iron to about 75# per square foot, and for four hours a fire was kept burning under it, maintaining a temperature of 1800°F. At the end of this time a stream of water at fire pressure was turned on it. The maximum settlement was about three quarters of an inch in the center of the beam, and pieces no larger than a man's hand fell off. The floor did not fail in any particular.

Art.XVI. Fire action on concrete.

Before concrete will disintegrate when exposed to fire, the large amount of moisture chemically combined in the setting of the cement, which is about twenty or twenty-five percent of its weight, has to be drawn off by heat, and the vapor thus drawn off has to be evaporated from the pores of the concrete before it becomes sufficiently hot to crumble. The slowness of evaporating this vapor is probably the cause of the concrete resisting extreme high temperature for a brief period of a few hours, while a much lower temperature, if long continued, will ultimately disintegrate it. Cement will resist 500°F. for an indefinite period, while a continuous temperature of over 700°F. is disastrous. The cement coating of the concrete will resist the attack of fire so long that it is of less consequence whether the stones can be damaged by fire or not. Thus, pure limestone is a most excellent aggregate, and will not decompose until after the concrete, and after the cement is gone, it is immaterial what aggregate is used, as the work has then failed anyway.

Art XVII. Conclusion as to fire-proofing qualities.

Thus it is seen that actual fire tests have demonstrated time and again the ability of this type of construction to withstand even the most severe fires. This is a valuable asset for concrete construction, as the plague of fire is known to everyone, and it is one of the greatest elements with which the builder has to contend.

Art.XVIII. Time required for building concrete structures.

Another point to be considered is the advantage of monolithic concrete construction over that of steel in the time required to build it, in other words, the speed with which it may be built. Mr. Edison, a man whose reputation is such that his experiments and conclusions are accepted almost as readily as facts, has proven that a concrete house can be built in much less time than any other type. This will be discussed at length later in the consideration of monolithic concrete construction. Consider, for instance, the construction of a steel building. The plans and specifications are put out, the contract is let, and the contractor is ready to begin work. First, he must buy his steel at as low a figure as possible. He consults the steel bids submitted and awards his contract to furnish the same. The steel firm has to get its force of draftsmen, shopmen, and others at work to figure out correct lengths and shapes, fabrication, details, and etc., in the consecutive order necessary for a smooth and efficient working organization on the job. The material must be shipped in installments which must of necessity be carefully checked and loaded. The chances for error in the drafting room, in the shop, or in loading, and the very obvious danger of a member becoming twisted or injured in some manner, and the further chance of a mistake at the building, make it naturally

a slow job. Consider, in contrast, the construction of a monolithic concrete building. As soon as the contract is let, the excavation made, and the footings in, the contractor may put on his force of laborers- for the actual mixing of the concrete does not require skilled labor- and begins to fill his forms. The sand, cement, and stone is brought in bulk, and the steel, too, for reinforcement is all ready for use the minute a small quantity of it arrives. The details for it and for the roof may not yet be completed, but that does not stop the progress of construction.

Art XIX. Example of comparative time for building.

The Dreymore Hotel, built of concrete, was up seven stories in the time generally required in getting the steel to the site.

In this day and age, and age in which competition, energy, and push are characteristic, the time factor is one of the most important considerations from the contractor's standpoint, as well as from the owner's point of view. The advantage which concrete has over steel construction is a commercial quality of no small value, and means much to the building world.

Art. XX. Resistance to shocks.

Engineers, owners, architects, and all who are interested in the construction of buildings are continually trying to get a structure which will withstand shocks and storms. A rigid, vibrant material transmits by vibration the sudden application of loads in whatever form they may come. Steel is, perhaps, as strong and as substantial a building material in its way as we know, and will stand very heavy impact, but the texture of steel is such that the stress is transmitted quickly and surely through the whole member. With wood the same thing

holds true. With stone and brick the stability is greater, but the strength is less. In a monolithic concrete structure, the concrete is made of substances which unit into the hardest possible stone for building. This insures the possibility of heavy compressive stress. Besides this stone, the concrete is reinforced with steel which strongly resists tensile stresses. We have, then, a structure built of the materials which serve to take care of the application of the stresses in the best possible manner. Besides this quality in the building we have a one-piece solid structure possessing the strength of stone and steel. It is a fitting testimonial to the power of resistance that the old buildings in Rome, and others which have stood so long against all kinds of attack, are stillthe good substantial concrete that they were when built. The endorsement by the various railroad companies of concrete bridges is an additional proof of the stability of such a method of construction. If structures are anywhere subjected to difficult strains, it is in bridges and especially railroad bridges. The solidity and entire lack of joints render it free from excessive vibrations often times experienced in steel structures. In riding over a bridge built of concrete, it is particularly pleasing to a passenger to note the absence of the familiar roar and lurching of the train which is often encountered in crossing a steel bridge. In tests made in France, double the load was dropped twice the distance on a reinforced concrete bridge than was done on one built of steel, and only one third the vibration produced. In the Blenheim Hotel, when the settlement was examined, it was found to be less than one eigth on an inch.

Art.XXI Stability of concrete structures.

The fact that ware-houses, machine-shops, and other buildings of

this nature are built of concrete, emphasizes the point of endurance, stability and resistance. For stability must be taken care of, and longevity and resistance are factors of great weight. This fact cannot be emphasized too strongly, and reinforced concrete construction so thoroughly embodies all of these that it speaks for itself more strongly than any argument that might otherwise be advanced. It has been found too, that expansion and contraction, which are important factors in buildings of this kind approach more nearly a minimum in monolithic concrete than in any other mode of construction.

Art. XXII. Quietness with which buildings can be erected.

A point in the erection of a building not often considered, is the quietness with which the work is carried on. Although this may not effect the cost of a building, it is mentioned here merely as an additional argument in favor of monolithic concrete construction. That this point has influence in the construction of a building is evidenced by the fact that it was the convincing argument in the decision to erect the Marlborough, Blenheim, and Treymore Hotels in Atlantic City. From this it seems safe to say that concrete construction is the quietest method known.

Art. XXIII. Forms are essential.

In considering the subject of monolithic concrete construction, the essential feature in the equipment is the forms. Monolithic construction without forms would be like carrying water in a sieve, or running a foundry without molds. The subject of forms furnishes a broad and extensive field for investigation and development. We shall not attempt to cover the subject in its entirety in this thesis. We shall give only a small part of what has been done, what has been tried,

or may eventually come to be in form work for concrete construction. Men have tried with varied success to invent a form economical in its use, strong, true and durable, and while a high stage of development has been reached, this part of the work is only in its infancy, and the possibilities of concrete construction, imaginative as they may seem today, lie in the development of an economical form.

Art. XXIV. The best material for forms.

It would be presumptuous to say what the best material for forms is or will be. Wood has been so much used that it is generally accepted as the only material that can be used. It has its advantages as well as its disadvantages. The increasing cost of lumber necessitates the adoption in the near future of some other material. We have in the course of our reading found many ideas of forms, such as metal lumber, devices for making or improving forms, short cuts in methods, ingenious contrivences for holding the concrete, metal forms, and etc. Each has its advocate, who presents its advantages in a clear, logical, and convincing manner, and as yet no different method has been accepted as standard. While every phase has been touched upon, yet the subject is considered new and in its infancy.

Art. XXV. Mr. Edison's opinion on the subject of forms.

Mr. Edison, a scientific investigator and inventor of international reputation, has given the question serious and careful attention for a number of years, and his deductions along this line should carry great weight in this Thesis. His experiments in form work for monolithic concrete residences will be fully described, and the comments of men experienced in this line of work will be given. Other form problems have been worked out and their solution will also be given. We have

sought to obtain information as to the best practice and ideas of forms, and such conclusions as have been drawn will be based upon the character of the acceptance and approval of the merits of the various forms.

Art.XXVI. Mr. Edison's concrete house.

The plan of Mr. Edison's concrete house proposition is briefly this; the completion of a set of steel molds which are so constructed that they will permit of repeated use and with varying design. In the construction of poured concrete, that is to say monolithic work, it is said that Mr. Edison has produced a mixture of the consistency of water which holds the aggregate in suspension, allowing the mixture to flow freely to all parts of the mold thereby securing a uniform distribution throughout the entire structure. The molds are capable of considerable variation of arrangement, thus making possible different styles of houses from the same set of molds. With a half a dozen sets, therefore, a wide diversity of styles would be possible. Mr. Edison and his engineers claim that the cost including the heating and plumbing will not exceed $1200.00 for a house to be built for one family on a lot 40×60 with a floor plan 20×30, having an eight foot porch in the front and a small porch in the rear. The house is to have considerable exterior ornamentation. The ornaments are to be cast with the house which will be reinforced concrete, including the roofs, floors, inside and outside walls, and stairs. Mr. Edison proposes to erect the molds in four days and to allow six hours after the molds are assembled for pouring. The house is to be completed within fourteen days after the pouring is made. It is estimated that with six sets of molds, one hundred and forty-four houses can be built in one year the same forms being used repeatedly. It is stated that most of the difficulties encountered in this

method of pouring houses have been overcome. A mixture has been found that can be readily poured and which will flow to all parts of the mold. A method has been evolved for removing the interior molds after the pouring has been done. The working out of the plan in detail is as follows. The monolithic concrete house is discussed from a practical as well as a theoretical point of view, and the conclusions drawn should have weight in the final decisions as to the advisability of a house so constructed.

Art.XXVIII. Description of Mr. Edison's house.

Reference is made to the "Cement Age" for 1908.

In order to effect the greatest saving in cost, speed in the actual work of construction, and the designing of a set of forms built of such a material that could be used many times with little work and little or no repair, the use of metal was decided upon. This is not necessarily a new material, although previously the practice has been limited to concrete chimneys. These concrete chimney forms were of boiler iron laced with angles. They were easily warped out of shape and unsatisfactory in many ways. The use of mill castings for forms overcomes the above objections, and furnishes almost an ideal form from the point of wear and tear. Their rigidity, which is absolutely necessary in concrete work, depends only upon the thickness of the casting. The placing of all the concrete at once was very naturally a result to be obtained, if such a thing were possible, although the placing of concrete for an entire house in a single day had never before been attempted.

Mr. Edison says that his original idea was to treat the house as a casting made of concrete. In making good concrete the molds must be perfect; the material from which the casting is made must be brought to a

fluid state, and adequate arrangements made to exclude the air.

The question of molds was solved by the use of cast iron. the next question was to bring the mixture of cement, water, and stone to as nearly a fluid state as possible. A colloid- namely clay- was used to accomplish this, and the result of the experiment tends to show that the use of this colloid will at least insure the running of the mixture to all parts of the form, and there will be no voids. The ejection of air may be accomplished in several ways, but the giving to the floor of a slight camber with a blow hole at the highest point seems to be the most feasible. With the mass flowing into every part of the form, the next question is: will the mass disintegrate due to the obstruction to free flow presented by the reinforcement and the necessary plumbing and heating pipes, and also to the action of gravity? The restriction of the flow due to the reinforcement will be more or less serious according to the size of the stone used. If one-fourth inch stone is used there will probably be no appreaciable resistance. No doubt, where the reinforcing is crossed or spliced, the larger stones will collect but this will be much like floating ice in a river held by a cluster of piles, the first piece sticks, then another and another, until finally, so much is added to the stationary pile that the whole is caught by the passing current and is swept away by the tide. The settling of the larger and heavier particles to the bottom due to the action of gravity depends more upon the disturbance of the mass after it is in place and also the speed with which the concrete gets its initial set than upon the action of gravity alone. There will be no settlement of stones to the bottom of the forms after the concrete has taken its intial set. The important point is to determine how the mass of concrete flows into the floor forms. Concrete has

an angle of repose but it is not certain what this angle is. Will the concrete upon being placed spread in a thin layer, say one inch thick over the whole area of floor forms, or will it fill the forms from top to bottom and be gradually worked from the sides by the pressure from the head of the concrete in the side walls assuming an angle of repose of say 30°? This would seem to depend upon the amount of water used, and this by the way is a very important factor.

The house represents a very ornate appearance, and though a less attractive building would cost less because of the simpler molds which would be used, the small additional expense representing not over an annual interest charge of forty dollars in the cost of forms, is more than justified by the improved appearance and general satisfaction to all concerned. This in itself is an argument for good, well-built, concrete houses at low cost because it not only argues well for attractive concrete design, but gets away from the idea of a dull monotonous building with no real beauty about it. There is, of course, the very obvious possibility that great irregularity of outline and elaborate detail might not be adaptable to concrete design, but that is a matter of judgement and taste, and one should weigh both sides of the question and design for both practicability and beauty. The proposed size of the building is 21 feet by 49 feet and 35 feet high not including the basement. The walls are to be 12 inches, reducing to 8 inches in the second story, the roof, 6 inches, and the floors and partitions, 4 inches. The location is important, and due to several considerations; first the reduction of first cost. This will be materially lessened if the building can be constructed on sandy or gravel areas, thus furnishing material for the concrete from the excavation. This, however, is a rather doubtful premise, for it is not

possible to depend upon this sort of a location. The necessity of having sand and gravel is of paramount importance, and it is fair to assume that in the majority of cases the sand, gravel, and cut stone would have to be brought from sources as near by as possible. In the construction of forms, we have the main argument, for it is here that the practicability is illustrated. Obviously, the use of economical forms is necessary, and if we do not bring this side of the question within the required limits, our monolithic structure is not the economical proposition that we think it is. The molds will consist of cast iron plates. The exterior plates for wall forms will be from three-fourths to seven-eights inches thick, the interior plates, one-half inch thick, the under side of the floor and roof molds, three-fourths to seven-eights inches thick, while the upper side one-half inch thick. All mold plates will have milled edges and faces, with flanged joints drilled for dowel-pin and bolt connection. Where intricate tracery and detail is attempted in the finish, the inside faces of the mold plates will be nickle-plated or faced with brass. It is expected that two houses per month can be erected from one set of forms, and with six sets, a reasonably good variety of design can be secured. The approximate cost of six sets would be about $105,000.00. The exterior and interior wall plates are connected and held in relative position by rods in pipe sleeves. The probability of occasional breakage in handling must not be overlooked, and the question of time and cost of renewal which may be allowed as a four percent depreciation is one of great importance. It would naturally be found advantageous to have the plates of as large surface area as possible, but this is limited by the use of cast iron of the proposed thickness, and also as the size of the plate increases, the danger of breaking is increased. By means of four small,

electrically driven derricks, Mr. Edison proposes to erect and take down the forms in four days, two four erection and two for dismantling. This, of course, might not be possible, as the forms might have to be handled in a different manner. The estimate of the approximate weight of the molds for one house is from 233,000# to 450,000#. This not only introduces the actual cost of transportation, this is the freight charges, but also the necessity of protecting some of the more intricate and decorative molds by crating in order to avoid the danger of breaking which adds materially to the expense. But this is taken care of in that the scheme is to erect houses in a row, and in large numbers at a particular locality, isolated houses not being the idea. Hence, transportation is not so large an item per house. The reinforcement for floors, roof, and elswhere when needed will consist of one-half inch and five-eights rods, to be placed in position before the pouring begins, and held by wiring or spacers. Pipes for gas, water, and plumbing, and ducts for electric wiring are set in position before the concreting operations begin, and the flues for chimneys are formed by thin metal forms which are left in position. For hotels and sanitary plumbing, the pipes may be left outside of the walls. The proposition is to have a one hundred horse-power boiler and engine on trucks to furnish the power to drive the motors connected with the four small derricks, concrete mixtures, elevator plant, and all other necessary power, and it is further proposed to instal mechanical mixers on the ground near the building. These mixers are so arranged as to discharged into a storage hopper from which concrete is conveyed by a bucket elevator to the distributing hopper at the top of the building from which the material flow through pipes into the molds. A specific gravity device is to be attached to the storage hopper and the

consistancy of the mixture carefully watched and kept uniform. It is also proposed to use plungers, power driven, operating from the top of the molds as the concrete rises, to keep same agitated and prevent seggregation of materials, and serving also to expel the confined air and secure a perfectly uniform face, and also assist in forcing the flow of material into and throughout the horizontal passages. Mr. Edison claims, that in experimenting, he finds that concrete of the proposed consistancy and composition expands a very small fraction of an inch in the greatest diameter of the house, and that subsequent expansion and contraction in walls can safely be neglected in the reinforcement introduced. This is a very important factor, as the expansion or contraction of metal in the forms might throw everything out of line or even break the form. The proportions of the concrete are as follows; one part cement, three parts sand, and five parts stone or gravel passing one-half inch mesh. The problem involved is to prevent seggregation of materials while being deposited and distributed, and the claim is that this difficulty has been solved by the addition of colloids or some electrolite in small quantities, which added to the viscosity of the combined materials, facilitates the uniform flow and prevents seggregation. Mr. Edison suggests that colors may be added to the mixture if desired, but adds that there is promise of success in his experiment with specially prepared paint for exterior application, which will penetrate and chemically combine with the concrete. This treatment is, however, a considerable item of expense, and is not figured in the original estimate, although that estimate included staining the walls, and red tiling color for the roof. The experiments were for variety of color. The experiments regarding uniformity and flow of the concrete were not at first satisfactory, but later experiments

were entirely successful, and it was stated that in actual construction it will be easier to secure uniform consistancy and composition. It may be granted that a system of iron molds accurately fitted and duly marked for quick assembling is entirely feasible. The estimate by Mr. Edison of 230,000# as the weight is not bourne out by another estimate which places the figure at 450,000#, which is given for the approximate area of 20,000 square feet of wall and floor surface above foundations, and this estimate does not include flange bolts and pins. On this basis, the cost of 450,000 pounds of castings would be about $40,000.00, as against $25,000.00 for 230,000 pounds of castings. This is on a basis of nine cents a pound, which must include planing the faces and edges for pin connections and nickle plating on the side next the concrete. This estimate as will be noted does nor include the cost of cellar wall molds.

Art. XXVIII. Results obtained by Mr. Edison.

In concluding the description of Mr. Edison's concrete house, it may be seen that certain definite results have been obtained. Mr. Edison has proved that a house can be built as a monolithic concrete structure, attractive in design, economical as to cost, and strong as to construction. Every practical problem involved can be solved, and a mixture of concrete can be obtained which will insure its flowing to all parts of the form, thus precluding the possibility of voids. The experiment has not been carried far enough to definitely determine that the addition of the necessary colloid does or does not delay the setting of the concrete or effect its strength. It does not determine whether the stone will separate from the cement and form a non-uniform mass, either in placing or at a later period due to the action of gravity. The first of the latter two effects the stability and must be solved definitely, before the

building of the house in this way can be accomplished. On the whole, the idea is one of rather revolutionary type to engineers, but from experiments that have been and are being made, it seems highly probable that a house can be sucessfully built in this way.

As we read of what is being done along the line of monolithic construction, we find examples everywhere of new methods and devices. It would be impossible to treat all in detail, but a few of the different forms will be taken up, not all, perhaps, being confined to house construction, though all applicable under certain conditions.

Art. XXIX. A concrete house at Pine Beach, New Jersey.

Reference is made to "Cement Age", Feb, 1911. Article by Oliver Randolph Perry.

In the house described in the following, double reinforced walls were used with an air space between, two inch tile being placed in the center of the form, with a concrete mixture poured on both sides of the form at the same time. This was done to economize time, construction, and cost. Portland Cement, with a 1 : 3 : 6 mixture for foundations, and 1 : 2 1/2 : 5 for above grade, was used. The bars were 3/8 inch placed two feet apart vertically, and and two feet six inches horizontally, and fastened at the junction by wire clamps. Wall thicknesses varied from ten inches for exterior double walls to four for interior walls. Wooden forms were built in convenient sections and held together by clamps. Exterior and interior wall surface resembled the rough, old-time sand finish. The interior walls were made smoother than the exterior because they were to be covered with a coating of various colors. The exterior walls received a thin wash of white beach sand and cement at the time of rubbing, this mixture taking the place of plain water for

wetting purposes. Concrete was mixed wet and was hoisted to a platform some forty-five feet from the ground and distributed by gravity to the walls below.

A swinging arm or V-shaped trough was used to distribute the concrete to points desired at such periods as were required. Skilled labor and and also material was difficult to procure at the desired, while rain was encountered almost incessantly, thus affording a severe test of the applicability of reinforced concrete to adverse conditions and weather. The roof is of reddish brown, cement shingles, which was in the nature of an experiment. The shingles are 6 inches by 12 inches by 1/2 inch, and weigh about one and three quarters pounds. They were stained with a waterproof stain.

A very strong point in this discussion is the variation in tone where the same stain is used in a quantity of shingles. This breaks up the monotony of the roof, and argues well for the adaptability of concrete construction, and it is noted here that in no particular does it fall short of fulfilling every requirement of exterior plaster, while at the same time supplying permanent construction which does not necessitate constant repairing, and plastering on interior walls. The concrete walls receive their colors direct, having a sand finish without cost, and at the same time being unbreakable and sanitary.

In further consideration of concrete houses, a point in their favor is that there will be little or no combustible material. In a concrete residence, there is little trim that cannot be made better and cheaper of Portland Cement than of wood. The chairs, rails, and picture molds can be made of concrete, the trim around the windows and doors can be molded in metal forms as cheaply as straight members. Even the wire-

moldings can be done away with, and conduits buried in the concrete partitions, walls, ceilings, and floors. The baseboard can be made of concrete or omitted entirely, as they serve no useful purpose in concrete buildings except in following wooden precedences. Windows may have cement sashes with wire glass and self-closing shutters, or self-dropping shutters of rolled up metal or asbestos. Metal furniture can be used, for eventually metal will replace the wood, and in future years as the supply of wood decreases, metal furniture will be all that can be found in the modern house. Thus, it will be seen, that every purpose for which wood is used may be accomplished by some other means.

Art.XXX. A successful form for monolithic construction.

Reference is made to "Cement Age" for Mar. 1911 By R.C.Lee.

The exact cost of wooden forms is hard to determine. The varying cost of lumber and labor in different localities, the amount of care insisted upon in the construction of forms, the complexity of design, and the scarcity of data on the subjectn make it a no light task. It is obvious that the cost of wooden forms is high for the reason that wood can only be used over a few times before it warps out of shape; saturation with liquid cement makes carpentering difficult, hardware is a considerable item, and experienced labor is essential. It is expensive to remove the forms without injuring the concrete as the forms must be left in place until the walls will not be injured by their removal. The following are some statistics on cost: reinforced concrete in factory construction; 45,502 square feet of wall surface; lumber for forms, $435.00, labor $5500.00. the average cost per square foot of surface was 13.1 cents. The average cost of forms for the Harvard Stadium, as given by Leonard C.Watson, President of Aberthaw Construction Co.,

Boston, was 13 cents. The superintendents report on the building of piers in the McAdoo Tunnel Yards in Jersey City, places the cost at 13 cents per square surface foot. The cost of false work runs from thirty to fifty percent of the entire cost of the walls. Ever since monolithic construction has become a factor in building, attempts have been made to get away from wooden forms. So far, the greatest difficulty with metal forms has been the initial cost, complexity of the process, and the seeming impossibility of getting a true surface. Most of the inventions to date have relied upon the superimposing of angle irons welded to unit plates and pinned together. Slight variations of the angle rim from a perfect right angle throws the whole line out of plumb, and the further necessity of superimposing holes for pins adds to the difficulty. To be successful, the metal form must combine great simplicity with great elasticity, so that inexperienced labor may be used and that alignment may be adjusted at any time. They must also be inexpensive and indestructable.

The Briscoe Spencer Co. of New York, has completed a factory that is 150 feet long, 50 feet wide, and 20 feet high, at South Elizabeth, New Jersey, for the General Carbonic Co., under the supervision of the Concrete Forms Co., 55 Liberty St., New York. The construction consists of a series of pilasters 3 feet by 1 foot, set on 19 foot centers, with 4 inch and 3 inch curtain walls, windows and doors of various sizes, and a poured concreti roof. The engine room contains piers and boiler supports of concrete. The entire building was erected with the Boswell steel concrete forms, and was the first building on which these forms were used. Common labor was obtained at from 16 1/2 to 25 cents per hour. The building, including the roof, contained 27,000 square feet of surface, and the entire cost of erecting the forms was $1,315.74, or 4.7

cents per square foot. The erecting cost was different in various parts of the work. The were 1550 square feet in the foundations, where the plates had to be put together in rainy weather in a ditch three feet wide and two and a half feet deep. The cost of this was $66.00, or 4.6 cents per square foot. The wall was carried up from the foundations straight for five feet, and the forms for this cost between 4 and 5 cents per square foot. When windows, doors, and offsets were encountered and the cost rose to between 3.8 cents to 6 cemts per square foot. The cost of laying the plates for the roof and supporting them was about 2 cents, the forms for the boiler piers was 1 cent. The cost of putting the plates in place rarely exceeded 2 cents a square foot, and the alignment in the shape was as true as the average wooden form. This was not good enough and absolute alignment was required. This, with washing and removing the plates raised the the cost to the above figures.

The swiftness of the work was pleasing. All hands spent the morning in erecting and removing the plates. The alignment was always verified by the foreman. The mixers were started and the pouring done the same day by the same gang which erected the plates. The work went forward at the rate of three feet a day, and the plates were removed and lifted each day. The system was easy and simple. It consisted of T-irons from 4 feet six inches to 7 feet long, perforated on the three flanges with 3/16 inch holes on 6 inch centers. From the middle flanie a movable arm projects with a turnbuckle on either side, used to true the walls by warping the iron in or out. The units on perfectly flat steel plates 1/8 inch thick, 1 inch wide, and from 6 inches to 6 feet long, weighing about five and a half pounds per lineal foot. A wedge clip for holding the plates together, a strip of metal to be embedded in the walls for

making the T-iron fast and to removed later, and a 7 inch hinge for making corners for any angle, complete the equipment.

The method of erection is as follows: a 2×4 is laid alongside of the excavation and movable arms lag-screwed to them. The alignment is rectified by turnbuckles. The plates are clipped to the uprights and wedged tight, and the concrete poured. The plates are removed the next day. the T-iron uprights are clipped to the metal ties embedded in the concrete, and the entire operation repeated. Great care must be taken in the alignment of the first tier of plates and should be verified by wooden spacers or gages. By this system, a single wall plates may be erected, or a wall battered at any angle. In walls over 6 inches, the uprights are set on 18 inch centers to prevent warping of the plates. Gummed strips of paper are used to prevent dripping through the cracks in the plates.

There are great possibilities in this system. The walls may be highly ornamented with bars, relief medallions, or conventional designs, walls of brick veneer, where the brick is one end of the form and the steel the other, is entirely feasible, and the construction of flying buttresses simple. The inventors say that dwellings can be made fire-proof, weatherproof, vermin proof, warm in winter, cool in summer, economical in repair, coal bill, and insurance, and be built cheaper than frame construction.

ArtXXXI. A large concrete sewer constructed with metal forms.

Reference is made to the Engineering News for 1908. Vol 1, page 336.

An excellent example of concrete form work is the construction of the sewer which discharges into East River at the foot of Truxton St., New York. The upper end of the sewer has two branches which meet at about half the total length of the sewer. The upper end of the main se-

wer which is 1635 feet long is 11 feet wide, and 7 feet and 2 inches high, and the lower end having a length of 1015 feet, is 11 feet 6 inches wide and 7 feet 8 inches high. One of the branches is 6 feet wide and 5 feet 6 inches high and 2800 feet long, and the other is 6 feet 8inches wide and 6 feet 1 1/2 inches high, and 1530 feet long.

The excavation of the main sewer runs through a slippery clay and an orange-peel bucket, having a capacity of one cubic yard was used. About seven hundred yards were taken out daily. This section was all sheet piled, about twelve thousand piles being used.

The supply of materials was brought by barges to the sewer and carried from there to the main storage bins by wagons.

The sewer was heavily reinforced by steel. The concrete was 9 inches thick at the crown and 12 inches thick at the floor. There were two layers of circumferential rods,of 3/4 inch twisted steel staggered, and placed about 10 inches on center. The two layers were about 10 inches radially. The reinforcement of the invert was similar. At the junction of the sides with the invert, four short rods 4 feet long, extended about 2 feet into the invert and lapped the arch reinforcement by the same amount, one for each circumferential rod. Longitudinal rods, 1/2 inch, and 12 inches on center, were wired to the inner layer.

The chief feature and novelty of the whole contract was the use of the Duralite Metal Forms. Two sets were used, one for the large, and one for the small sewer, although one set could have been adjusted for both curves. The forms for the large sewer were made of No.16 gage sheet steel with 3 inch corrugations, and those for the smaller sewer of No.18 gage sheet steel with 2 inch corrugations. The forms were made up of standard units, 3 feet long and 28 inches wide. The exact circumferential

width was obtained by using wooden strips at the lower sections. The outer surface of the forms consisted of a plain steel sheet to which was riveted on the inside a corrugated sheet to give the required stiffness, and eliminate any necessity for interior centering or bracing. To the under side of the corrugated sheet were attached by adjustable means a number of flat bands, varying in number from three to five for each section of 3 feet according to the size of the sewer. These serve to furnish first a bottom member to the assemblage of outer sheet and corrugated sheet, thus forming a strong Warren truss, second adjustability to any required curve, and third by means of lapping the consecutive sections so as to secure perfect alignment without extra labor.

The curve adjustment was secured as follows: the bands were attached to the sheets by T-headed bolts, whose nuts bear on washers having the hole concentric to the outer circumference, which latter fits into a circular center bore in the band. The units were shipped to the job flat and were bent to the required curve over templates. After being bent, they were held rigidly to this shape by screwing up the bolts with the proper position of the several eccentric washers. They then require no further adjustment until it is necessary to change the radius. The lower section on either side is connected with the main part by a hinge rather than a fish plate. By swinging the lower section inward and upward, the entire section could be lowered and pushed through the form ahead. For the purpose of aligning the successive sections of the completed form, the band at one end of each section was so placed as to project one inch beyond the form, while the band at the other end was set back one inch from the end. This produced a one inch lapping of successive sections, so that when one section was set up against one

already erected, it came easily and exactly into alignment. When so set, the clamps were sprung over the adjoining end bands, which held the new section rigidly in place.

Thus a form of any size or shape could be made of these units, the only limitations being that as the sewer became larger or smaller, different sized iron and corrugations were used to carry the difference in stress. The manu facturers furnish the sections with corrugations of two, three, four, and five inches deep, and of No.13 to No.12 gage steel, to be used in sewers from three to twenty feet in diameter. These forms make possible the conducting of concrete construction as a continuous operation, an important factor as regards economy and quality of work. The y give a remarkably smooth finish difficult to obtain with other than a metal form.

On this work the forms were left in place two days after the concrete was placed. The average progress per day was twenty-four feet, therefore nine sections of eight feet each were required. The rear-most section was struck by drawing in the hinged section and lowering the whole to a curved cart by which it was pushed forward to the required place. The operation took four men thirty minutesfor each section of eight feet, or one hour and a half for twenty-four feet.

At an average cost of $.25 per hour for labor, and adding $.50 for cleaning and greasing the forms, the cost for labor for shifting was $2.00 for the twenty-four feet. There was 456 square feet of surface, the unit cost of moving forms was 8 1/3 cents per lineal foot of sewer, or .44 cents per square ffot of surface.

These forms are advantageous for reasons as follows: first, the non-absorbant forms make the best concrete, these forms being of steel

are necessarily non-absorbant. Second, certainty of correct alignment, third, smoothness of concrete surface, fourth, facility of applying heat by salamanders, there being no danger of fire from steel forms, fifth, repair and maintainance cost low, sixth, cost of moving and setting low, seventh, lightness of weight per square foot of these forms- in a six foot sewer, this amounts to about four pounds, while wooden forms for a sewer of the same size, will weigh about sixteen pounds per square foot of surface. Eighth, unobstructed bore- this feature is very important, since it gives a free passage for men, materials, and forms. This latter is almost essential for continuous operations.

These forms were not used on the curved portions of the sewer except where the angle was so gradual that it could be taken up with the one inch lap at the end of the section. The sharp curves were concreted over wooden forms. The connection to the sewer were made by tile trimmed at its inner end to the curve of the inside form and concreted in place. The invert was made without forms. The outside of the arches was made of plank and built in the conventional way, the height depending upon the consistency of the concrete

Art. XXXII. A traveling mold for making reinforced concrete pipe.

Reference is made to Engineering News for 1908. Vol 1, page 134.

A portion of the Slat River project of the United States Reclamation Service consisted of a nineteen mile canal that carried water for power. At two places, it crossed depresions, at both of which the crossing was made on tangents with the inverted siphons of reinforced concrete pipe, which was built on the ground by a movable form called an "alligator", invented and designed by F. Teichman.

The two crossings were made at Cottonwood Canyon, where the length is 250 feet, and the head 75 feet; and at Pinto Creek, with the length of 2130 feet, and a head of 85 feet.

The forms consisted of an outside detachable frame work of steel, with wooden lagging, and an inside form made of steel.

The inner mold was made of three functionally different parts: the lower front part of the mold, which was slowly pulled along with the progress of the work, and went by the name of "alligator", the upper stationary plates, and the lower stationary plates. The upper stationary plates were erected over the slowly moving alligator, and supported by rails which were a part of the moving form. The plates of the alligator formed the lower part of a circle, and the upper stationary plates formed the upper half of the circle 5 feet 8 inches in diameter. As the upper stationary plates were built up in half cylinders, they were bolted to the half cylinders of the previously erected plates, so that the upper stationary plates formed a rigid half cylinder of about 70 inches in length. The half cylinder of the alligator had a length of about 24 feet and 6inches, and beyond that toward the front end, the alligator sloped to a point for about 10 feet. The rails of the alligator which supported the upper stationary plates extended a few feet beyond the rear end, and as the forms were pulled away from under the stationary plates, each individual half cylinder, while it was supported by the projecting rails was given a support by a pair of lower stationary plates, introduced into the space vacated by the alligator.

The transportation of the parts of the inner mold from the rear end where they were dismantled, to the for ward end where they were erected, was accomplished by a car on rails inside of the mold that was moved along

by ropes operated alternately by the erecting plate men and the dismantling plate men. All parts except those of the alligator were of such weight that one man could handle them without difficulty.

The actual method of construction was as follows: the alligator was moved forward with the sloping edge just a little ahead of the working face of the concrete. The upper stationary plates, dismantled at the rear end as the cement had set sufficiently, were brought forward on the car and erected over the alligator, and bolted to the previously erected half cylinder of the upper plates. The car was returned and brought forward the lower stationary plates, dismantled and placed on the partially set concrete between the last exposed lower plate and the head of the alligator. Thus, these form the support of the upper stationary plates, which were still supported by the projecting rails of the moving form, but would soon lose their support as the alligator was moved forward. The reason of the tapering form of the sliding mold was to have the working face of the concrete at or near the edge of the taper, and thus readily accessible and in full view. The tapering form of the sliding mold was patented by Mr. Ernest L. Ransome in 1885, and was used in constructing concrete lined ditchesand open conduits for cable-ways and etc. The alligator of Aruzona has six articulate courses, five half cylinder courses, each 39 inches long, and a front course 12 feet in length which has a taper of about 10 feet. The courses are held together at the bottom of the semicircle by bolts held against angle irons riveted to the plate, and near the upper edge of the courses by two draw bars, 1 inch by 2 1/4 inches, laid between the angleirons and pinned to the same. By removing these pins, the draw bars can be removed, and by removing also the bolts at the bottom line, the alligator is di-

sected into six parts ready for transportation.

Each course of the alligator has a horizontal stay of a 5 inch channel to which is bolted the two rails of the track that projects about two feet over the end of the cylinirical part of the alligator. The connection of these channels with the cylindrical plates of the form permits an expansion or contraction of the form with out effecting the track. At the bottom of the form are two half rounds which form the track for the car that is used in bringing the dismantled plates to the front. The different horizontal angles and half rounds that are riveted to a course which reach sligtly over the ends of the course and are cut there on a slant so as permit a light projection of the half rounds to the next course, thus holding the different courses in alignment. The alligator is pulled ahead by means of a 7/8 inch steel rope about 500 feet long, to any point of which could be clamped a two Sheave block, the second block being tied to a dead man about 600 feet ahead of the mold. The 9/16 rope of the blocks was taken sidewise to a capstan which was operated by a horse. For the guidance of the moving form, a track of 2×4 scantlings was placed in the ground on a line with the base of the excavation, and an outrigger of the alligator slid thereon.

The upper stationary plates were 24 inches wide. Each course was hinged in three parts. At the hinges, the connection of the plates was stiffened by circular bars bolted between the courses. The side plates of each course had movable castings, by means of which and of the wheeled axles, each course rested on the rail of the alligator. The castings had clips, screws and pins. The clips locked into the notches of the axle, and by means of the screws, the clearance between the upper edges of the alligator plate and the power edge of the stationary plate was adjusted.

The pin held the axle in position in the casting. With the pins removed, the axle could be removed or inserted horizontally. If the withdrawal of the alligator should be impossible, the inner forms could be removed by first removing the axle. The upper stationary plates, beginning with the side plates could be removed by swinging them toward the inside, thus contracting the side plates of the alligator by operating the nuts in front of the six 5 inch channels of the six courses of the alligator.

The function of the lower stationary plates was to support the upper stationary plates after the projecting rails of the alligator had ceased to support them. The lower part of the power plate must have a certain flexibility to accommodate itself to the partially set concrete and the upper part must be made to withstand a much larger outward force than is required for the support of the invert at that point. The plates were made in halves and pinned together at the bottom line. They were two inches shorter than the upper plates, but the half rounds of the track of the lower plates were as long as those of the upper plates. For the purpose of alignment, the rounds were cut on a slant. The upper ends of one pair of lower stationary plates were reduced in width and stiffened and connected by an adjustable horizontal tie rod. A jack screw which was turned by hand has a clutch on one end which fits over the axle of the upper plate and was ground to a point on the other end which fitted into a depression in the tie rod. With a little practice, the plate man soon learned to give the jack screw the proper turn so that the upper plate had the same amount of support as given by the rail of the alligator.

As the alligator moved along, a space opened between the foremost lower plate and the end of the alligator in which there was no track for the car. This difficulty was obviated by a track bridge, one end of

which was fastened to the foremost lower plate, the other end resting on the rear of the alligator, sliding as the latter moved along.

The outer mold was a steel skeleton frame covered with a wooden lagging, the ribs made of steel flat bars, were held equidistant apart at the lower end by a device in the bottom lagging, and half way to the top by a notched rod which fitted over each rib.

Owing to the slow setting of the concrete, only about forty feet of pipe could be constructed per day. The concrete was hand mixed in the proportions of one part cement, two and one-half sand, and four of gravel, a wet mixture being used through out. The entire cost of labor including the foreman and time-keeper, screening and hauling the the gravel, pointing and brush-washing the inside of the pipe, and wetting the outside, building the scaffolds and forms, repairs, and bending and placing the reinforcement, was about $2.50 per foot of pipe, or about $6.50 per yard of concrete. The work on the whole was satisfactory, but for continuous work by using a longer form and a quicker setting cement, 250 feet for twenty four hours could easily be accomplished.

An improvment on the form would be as follows: two 4×6 sills placed on the base of the excavation, the distance between their 4 inch faces being equal to width of the base of the pipe. This would form a track for the moving alligator and would also serve as the bottom lagging for the moving form. In this manner, the concentricity of the outer and inner forms would be gained. No special track would be needed for the alligator and the ribs of the outer mold would not be supported by the same struc-ture that carries the planking for the wheel-barrows. This latter is very objectionable, as the moving loads tend to create vibrations in the partially set concrete. With improved conditions of concentricity, and this

lack of vibration, the thickness of the reinforced pipe could be reduced at least one inch.

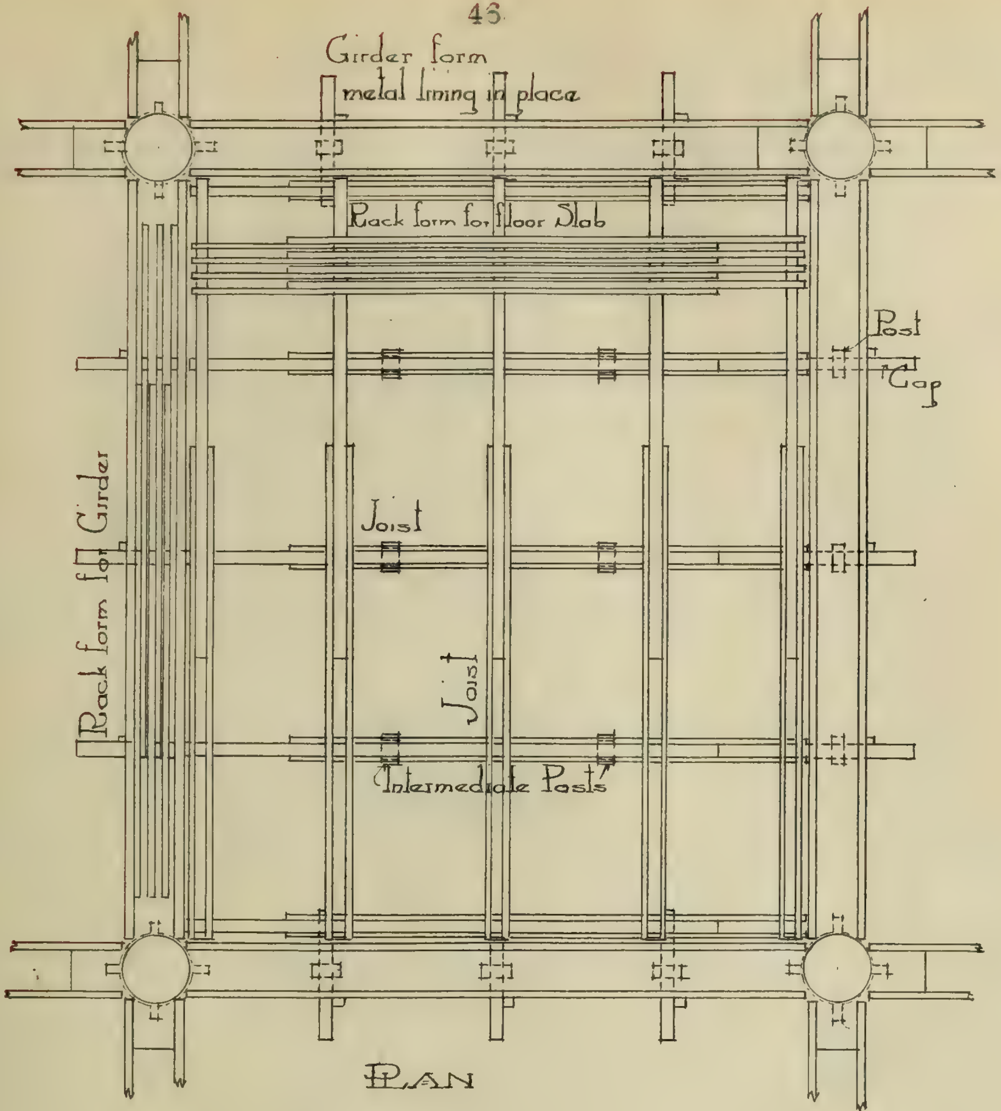
Art.XXXIII. Adjustable and portable forms for concrete construction.

Reference is made to the Engineering News for 1908. Vol 1, page 264.

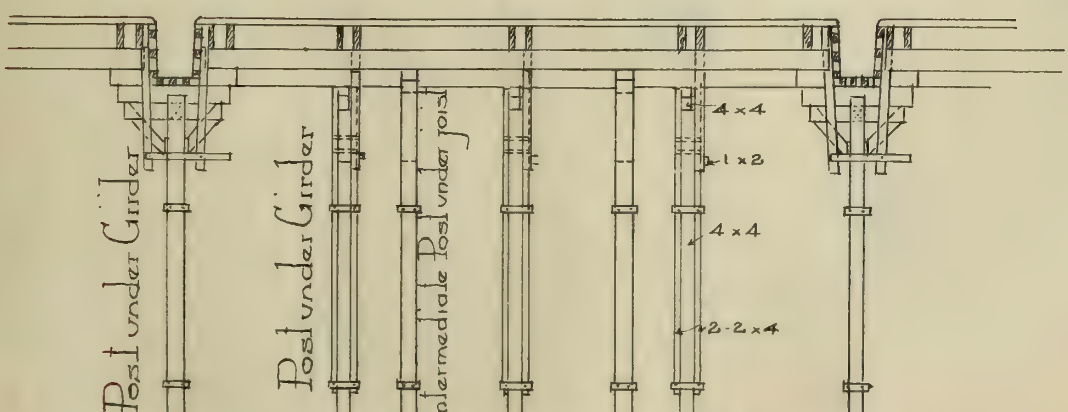
The following is a system of forms which can be used over and over again, and which were recently used in Chicago, Illinois.

The principle of the design is clearly shown in the drawings. The posts are telescopic, with a 4×4 for the lower section, and two 2×4s for the upper section. The height can be adjusted by means of holes and can be secured by clamps and bolts. The girder forms rest on cross pieces of the posts and are also telescopic. The bottom and sides of the form are made in units of two pieces of 2×4s which slide on one another so that the length and to a certain extent the breadth, may be adjusted. The cross pieces of the posts support the joist, and on the top of these joists is laid another set supported by the first. The racks forming the centering for the floors are laid on the joists, and are telescopic. All of the forms are lined with galvanized iron pressed to shape and the floor centering with straight, flat pieces.

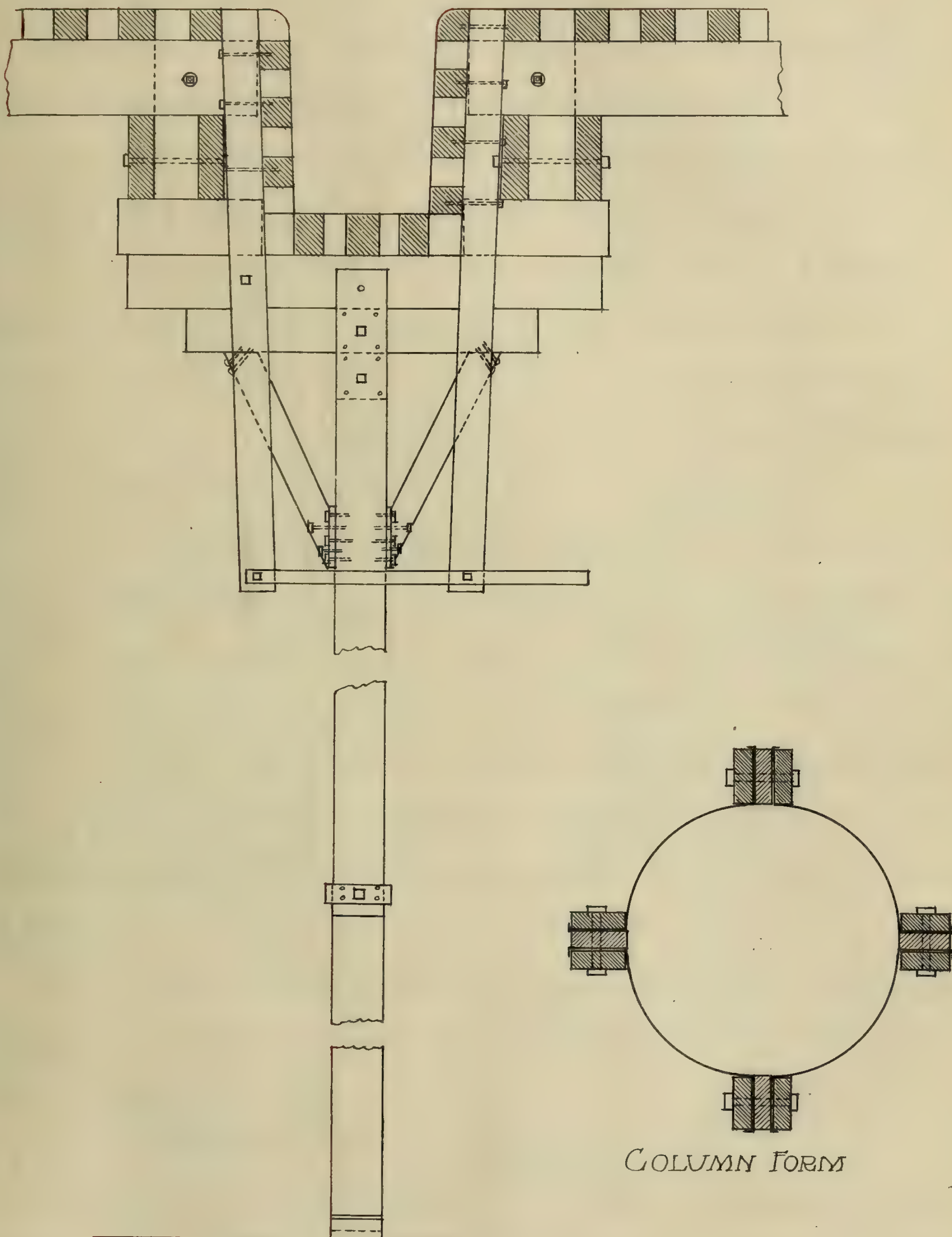
The column forms are composed of four strips of galvanized iron, with the vertical edges flanged and fitted between timbers which give the necessary stiffness and are bolted together. The sides of the column may be varied by inserting filler strips between the flanges as shown. All sectional parts of the form are bolted together so that they may be easily erected or taken down and packed for transportation. The erection and removal can be done by laborers, thus dispensing with practically all carpenter work.



PLAN



SECTION



COLUMN FORM

DETAIL OF GIRDER FORM WITH SUPPORT

ART. XXXIV. A corrugated steel centering for concrete work.

Reference is made to the Engineering News for 1908. Vol 1, page 116.

This is a system of corrugated steel forming for concrete wall and sewer construction, invented by Mr. Keith O. Guthrie.

The new form called "Duralite" is made of two light gage steel plates fastened to a separating layer of specially corrugated steel sheeting. The depth between the outside sheets is varied from 1 1/2 inches to 3 inches according to the requirements of the work. The gage of the sheets running from No. 16 to No. 24. Under test, a flat section weighing four pounds per square foot, developed a resistance of about twice that of ordinary yellow pine.

When used as wall forms for flat panels made up of suitable sizes, they are much stronger than the usual plank forms, and therefore permit of the studding placed at much greater intervals than the regular timber forms. In using the sheeting for curved forms or centers for small arches,culverts, and sewers, the inside strip of steel is replaced by narrow strips or bands, spaced about 2 feet center to center, and the bolt holes on the inside face are so placed that the whole truss plate is drawn into any curve desired.

This system is especially adapted to sewer molds, on account of the absence of any inside bracing, and the ease with which it can be moved along in continuous work.

Art. XXXV. A concrete side-walk machine.

A traveling mold was invented by Mr. Ernest L. Ransome, which is used for the construction of concrete side-walks, unit slabs, lintels, and other members of uniform cross section. The mold is placed on the sight of construction, and drawn ahead by power, leaving the finished

product behind. Mass concrete for the base of the side-walk is filled in a hopper in the front part of the mold, and the finishing or top mortar coat in a hopper in the middle, so designed that as the mold is drawn along, it feeds a layer of mortar on the concrete base. No skilled finishers are required with the mold, but a smooth top coating and a solid base are automatically secured at the rate of about two feet a minute.

Art. XXXVI. A traveling form for constructing the invert of concrete sewers.

A plate of steel 1/4 inch thick, and 6 feet 2 inches long was bent to a semicircle with a radius of 18 inches at the side, and extended on a tangent to the curve above about 6 inches. Above the plane of the horizontal diameter, the front was opened and stiffened by a 3 inch angle riveted to it, with a horizontal angle across the upper end, while the rear open end was held apart by a 2 inch by 1/2 inch iron bent down and riveted to the inside of the steel plates near the top edges. Along the inside of the shell, longitudinal angles 1 1/2 inches were riveted with the horizontal legs up, and 1 1/2 inches above the horizontal diameter.

Art. XXXVII. Conclusion.

We have in the course of this Thesis found out what has been done and to a certain extent what can be done in monolithic construction. Our conclusions are definite in our own minds, and in stating them, we do not assume that they are conclusive of the whole subject. In fact, the writing of a Thesis on this subject only serves as an introduction to or a basis for future study and development of this method of construction. There seems to be no doubt that real true design of a monolithic concrete structure is not only possible, but is capable of very attractive designs and most desirable results. The one condition under which this material may be used as being adapted to design, is that it must be treated as an individual and entirely separate material, for the problems of design are peculiar to the nature of the material. Again, it seem equally true that concrete is the most durable of all building materials, not only holding its initial strength, but increasing it with age. Analysis of the concrete which was made two thousand years ago plainly demonstrates the truth of this statement. By actual test in experiments, by the endorsement of railroads, and by the examination of buildings which have been subjected to severe strains, the strength and stability of monolithic reinforced concrete is clearly demonstrated. These characteristics are essential properties of good construction, and point out to the future the advantages of this type of building over others. Speed in getting the work along on a building, systematic organization of the labor necessary for erecting a structure in this manner, and the comparitive quietness of the operations, are but other additions to our argument for monolithic concrete construction. The development to a high degree of forms for the erection of a building, the

possibilities already advanced in the innumerable inventions of forms, seem to make this part of concrete construction an important factor in its adoption. It is a subject for careful criticism and thought. The results obtained thus far speak well for this side of monolithic construction.

From the foregoing it must seem that monolithic concrete construction has before it a most brilliant future, and the high point of efficiency which even today it has obtained is but an indication of the position it will occupy in the near future. Its possibilities; its scope, wide; and its examples, numerous and wonderful; while its acceptance by the building world is becoming more universal day by day.

Bibliography.

Cement Age:

During the years from 1904 to 1911

Cement Era:

During the years from 1906 to 1911

Construction:

March, 1911

American Architect:

During the years from 1908 to 1911.

Scientific American:

Volume 97.

Scientific American Supplement:

For the year 1904.

Report of National Orginization of Cement Users:

For the year 1909.

Engineering and Contracting:

During the years 1909 and 1910.

Electric Railroad Journal:

For the year 1910.

Applied Science:

For the year 1909.

Engineering Society of Western Pennsylvania.

Report of the American Society of Civil Engineers.

Letters from Manufacturers of Cement Devices.

Modern Advertises.

Bulletin No.13, issued by Association of American Portland Cement Manufacturers.

Publication of Universal Cement Co., on Standard Specifications.

Concrete in Railroad Construction, published by Atlas Portland Cement Co.

Concrete Garages, By the Atlas Portland Cement Co.

Concrete in Highway Construction, by the Atlas Portkand Cement Co.

Concrete Construction on Home and Farm.

Bulletin No. 403, United States Dep't of Agriculture.

A Successful Metal Form for Monolithic Concrete Construction published
by Concrete Forms Co., of New York.

Engineering News:

During the years from 1906 to 1911.